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# A Novel Medial Soft Tissue Release Method for Varus Deformity during Total Knee Arthroplasty: Femoral Origin Release of the Medial Collateral Ligament

Seung-Yup Lee, MD[1], Jae-Hyuk Yang, MD[2], Yong-In Lee, MD[2], and Jung-Ro Yoon, MD, PhD[2]
[1]Department of Orthopedic Surgery, Seoul Barunsesang Hospital, Seoul; [2]Department of Orthopedic Surgery, Veterans Health Service Medical Center, Seoul, Korea

**Introduction:** Numerous methods of medial soft tissue release for severe varus deformity during total knee arthroplasty (TKA) have been reported. These include tibial stripping of the superficial medial collateral ligament (MCL), pie-crusting technique, and medial epicondylar osteotomy. However, there are inherent disadvantages in these techniques. Authors hereby present a novel quantitative method: femoral origin release of the medial collateral ligament (FORM).
**Surgical Technique:** For medial tightness remaining even after the release of the deep MCL and semimembranosus, the FORM is initiated with identification of the femoral insertion area of the MCL with the knee in flexion. Starting from the most posterior part of the femoral insertion, one third of the MCL femoral insertion is released from its attachment. If necessary, further sequential medial release is performed.
**Materials and Methods:** Seventeen knees that underwent the FORM were evaluated for radiological and clinical outcomes.
**Results:** Regardless of the extent of the FORM, no knees showed residual valgus instability at 24 weeks after surgery.
**Conclusions:** As the FORM is performed in a stepwise manner, fine adjustment during medial release might be beneficial to prevent inadvertent over-release of the medial structures of the knee.

**Keywords:** **Knee, Arthroplasty, Medial collateral ligament**

## Introduction

Since varus deformity is frequently encountered during total knee arthroplasty (TKA), precise medial release is instrumental to obtain balanced rectangular flexion and extension gaps[1)]. The classical medial release consists of osteophyte removal, deep medial collateral ligament (MCL) and posterior oblique ligament (POL) release, semimembranosus release, posterior capsule release, superficial MCL release, and pes anserinus tendon release in a sequential manner[1-3)]. In moderate to severe varus knees, release of the tibial insertion of the superficial MCL or pie-crusting of the MCL midsubstance can be a solution[1,3-5)]. Although most varus knees can be dealt with these procedures, inadvertent over-release of the medial structures, especially the superficial MCL, can occur during procedure in knees with severe varus deformity[2,4-7)]. Alternatively, medial epicondylar osteotomy has been presented with satisfactory clinical outcomes in severe varus knees[2,8,9)]. This technique can be advantageous over the superficial MCL release because it is based on the bone-to-bone healing and does not manipulate the broad tibial insertion of the superficial MCL which requires an extensive soft tissue healing process[2,9)]. Engh and Ammeen[9)] described tibial stripping of the superficial MCL as an all or nothing procedure. However, we think over-release can also occur after medial epicondylar osteotomy for medial release.

Irrespective of the medial release technique utilized, the MCL is the primary structure of interest. In particular, our focus has been primarily on the femoral side of the MCL. Laprade and Wi-

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Correspondence to: Jung-Ro Yoon, MD, PhD
Department of Orthopaedic Surgery, Veterans Health Service Medical Center, 53 Jinhwangdo-ro 61-gil, Gangdong-gu, Seoul 05368, Korea
Tel: +82-2-2225-1352, Fax: +82-2-2225-1910
E-mail: momyjr@naver.com

jdicks[10] reported that the superficial MCL attaches slightly proximal and posterior to the medial femoral epicondyle. The femoral attachment of the deep MCL is distal to that of the superficial MCL. The femoral attachment of the superficial MCL is round to oval in shape, and anteroposterior (AP) width of it is approximately 12 mm[10,11]. Unlike distal sliding osteotomy of the femoral condyle or medial epicondylar osteotomy including adductor magnus tendon attachment, we have concentrated on the MCL femoral attachment site because soft tissue-to-soft tissue healing under conservative therapy has been known to be satisfactory in MCL injuries[2,9,10].

We present here a surgical technique devised to facilitate quantitative stepwise release in severe varus knees. We suggest this technique as a more simple, reproducible, and less invasive method compared to medial epicondylar osteotomy.

## Surgical Technique

The surgical approach and initial steps are the same as in the conventional TKA procedure[12]. Medial osteophytes of the femur and tibia are removed first. Then, deep MCL is released along the medial meniscus 3–5 mm below the medial joint line; release of the POL and semimembranosus are not included in this procedure. Next, distal femoral and proximal tibial resections are performed. Upon complete femoral resection, preliminary gap assessment is done using a gap spacer block. Both flexion-extension gap balance and mediolateral gap difference are evaluated with the spacer block inserted into the flexion and extension gaps. Relative medial tightness compared to the lateral gap can be detected 1) if insertion of the spacer block is difficult due to the small medial space, not due to the lateral space and 2) if tilting of the inserted spacer block is easy in the lateral portion but not in the medial portion. Such medial tightness can be mostly resolved with further medial soft tissue release that involves direct head of the semimembranosus and femoral side posterior capsule. However, further release of the medial structures is required to achieve a rectangular mediolateral gap in some severe varus knees. In this circumstance, femoral origin release of the medial collateral ligament (FORM) can be utilized as the final step of the medial release.

With the knee flexed, the FORM is initiated with identification of the femoral insertion of the MCL. Palpating the taut MCL structure, the femoral insertion of the MCL over the medial epicondyle and medial sulcus is identified in the AP direction (Fig. 1). The femoral insertion of the MCL shows morphologically long AP width with relatively short proximal-distal length which is somewhat oblong[11]. Upon identifying the anterior-most and posterior-most parts of the femoral insertion of the MCL, the AP width of the MCL is measured (Fig. 2). The anterior-most part of the MCL can be detected by tactile sensation, which shows difference between the hard MCL tissue and the soft tissue anchor. If an obvious medial extension-flexion gap imbalance is encountered before medial release, other medial release techniques rather than the FORM should be considered because the latter technique would only correct the mediolateral imbalance not the extension-flexion gap imbalance, resulting in significant extension-flexion imbalance after release. The FORM can be divided into three steps according to the AP width. From the posterior-most part of the femoral insertion, one third of the MCL femoral insertion is released from its bony attachment using a

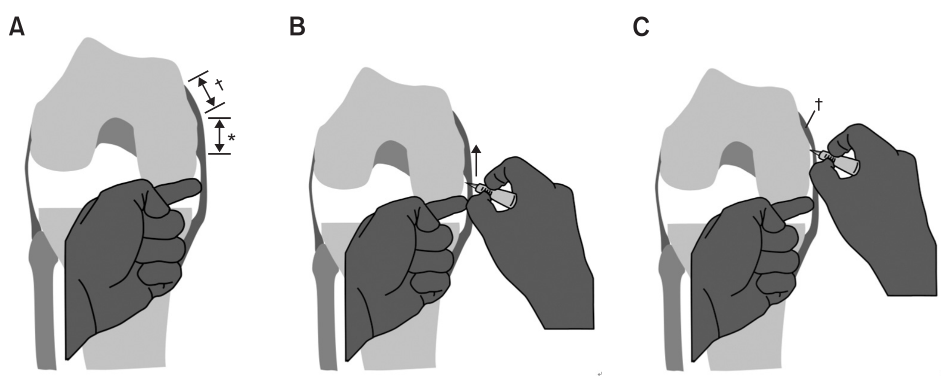


**Fig. 1.** Schematic illustrations of the FORM technique. (A) With the knee flexed, the FORM is initiated with identification of the femoral insertion of the MCL. Palpating the taut MCL structure, femoral insertion of the MCL over the medial epicondyle and medial sulcus is identified in the antero-posterior direction. The asterisk (*) indicates the length of the actual MCL femoral insertion. In front of it, superficial fibrous strands attached to the femoral attachment site of the MCL are present over the medial femoral condyle (†). (B) Using a No. 11 blade, the FORM is performed in the posterior-to-anterior direction. (C) The FORM can be done as much as necessary (1/3, 2/3, or complete). The illustration shows completion of FORM. Note that the soft tissue anchor (†) is preserved. FORM: femoral origin release of the medial collateral ligament, MCL: medial collateral ligament.

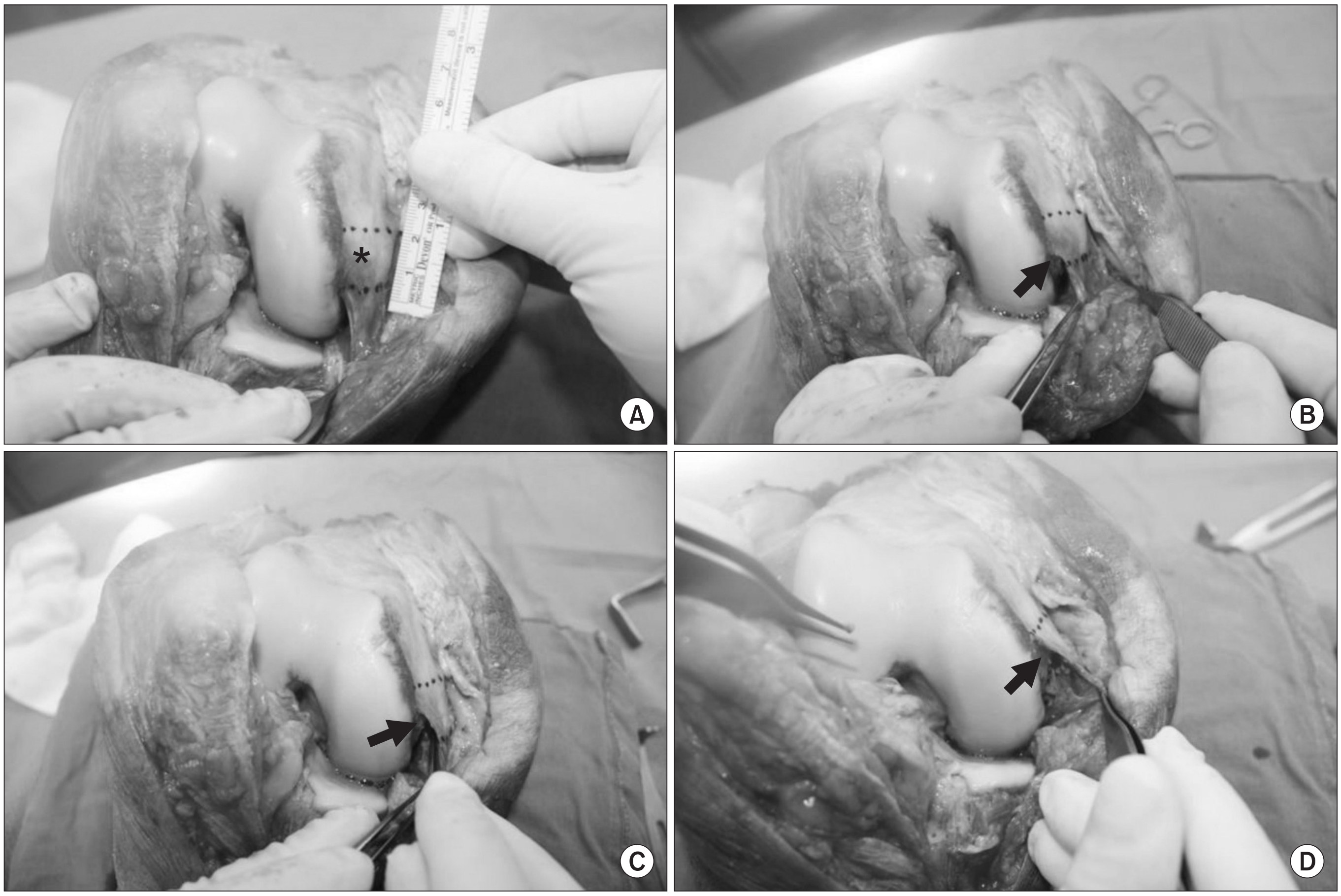


**Fig. 2.** The FORM technique demonstrated in a cadaveric knee. (A) Identification of the femoral insertion of the MCL (asterisk). A ruler is used to measure the distance between the anterior-most part and posterior-most part of the femoral insertion. (B) One third of the MCL femoral insertion has been released (arrow). (C) Two thirds of the MCL femoral insertion has been released (arrow). (D) Completion of FORM (arrow). Note that the superficial fibrous strand in front of the MCL femoral insertion is intact. FORM: femoral origin release of the medial collateral ligament, MCL: medial collateral ligament.

No. 11 blade (Fig. 1). Following this step, mediolateral balance of the flexion and extension gaps are examined using the gap spacer block. If medial tightness still remains, further two-third or complete FORM can be performed step by step. Each step is followed by gap assessment to determine further conduction of the FORM. Even with the complete FORM, superficial fibrous strands attached to the femoral attachment site of the MCL are preserved to promote postoperative soft tissue healing (Figs. 2 and 3). No suture or fixation is added to the site of FORM. Since we suppose that mild under-correction of medial tightness can be slightly loosened and adapts to the gap derived from real prosthesis and bearing, aggressive over-correction should be avoided.

Postoperatively, continuous passive motion and tolerable weight-bearing exercises are started the day after surgery. In our patients, an MCL brace was also applied for 6 weeks after surgery to prevent subsequent medial instability[10], considering this novel technique lacks sufficient clinical data.

## Materials and Methods

From January 2013 to November 2014, 121 knees underwent posterior-stabilized TKA. All the operations were performed by a single surgeon (JRY). Among them, the FORM was performed in 17 knees (14 patients). There were 5 males and 9 females. Their mean age was 72.4 years (range, 63 to 85 years). With informed consents, we retrospectively reviewed the medical records and radiographs of lower extremities of all patients. The extent of the FORM (1/3, 2/3, and complete), thickness of the tibial insert, and degree of intraoperative valgus instability were recorded. For radiological evaluation, we used pre- and postoperative standing AP radiographs of the entire lower limbs. The hip-knee-ankle (HKA) angle was measured on these radiographs; an HKA

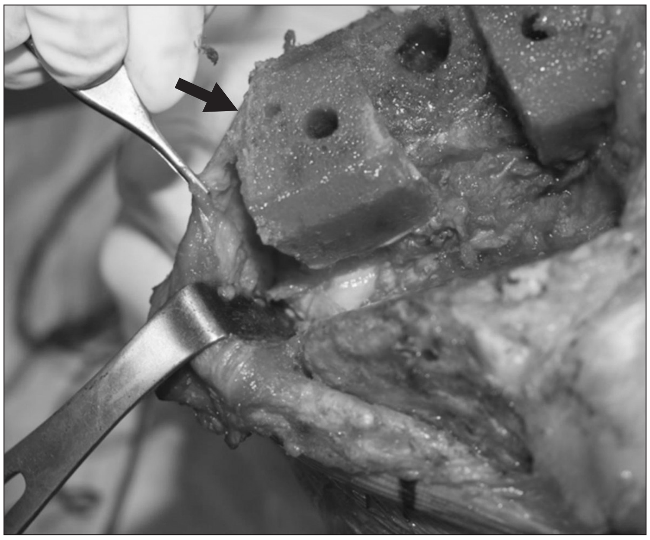

**Fig. 3.** Intraoperative photograph taken during total knee arthroplasty. Although the femoral insertion of the medial collateral ligament (MCL) is completely detached from the femur, soft tissue is connected from the femur to the detached MCL insertion (arrow).

angle of <180° indicates varus alignment. For clinical assessment, radiographic degree of valgus instability (preoperative under anesthesia and postoperative 12 and 24 weeks), Knee Society score, and range of motion (ROM) were evaluated. Radiographic valgus instability compared to the contralateral knee was defined as follows; grade 1 as <5 mm opening, grade 2 as 5–10 mm opening, and grade 3 as >10 mm opening. The mean follow-up period was 8 months (range, 6 to 15 months). The mean comparisons of clinical outcomes were performed with the Wilcoxon signed rank test. A p-value of <0.05 was considered statistically significant. Statistical analyses were performed using SPSS ver. 16.0 (SPSS Inc., Chicago, IL, USA).

## Results

The thickest tibial insert used was 14 mm (11.5±1.3 mm). The extent of the FORM was as follows: one third in 8 knees, two thirds in 4 knees, and complete in 5 knees. In all 5 knees that underwent complete FORM, superficial fibrous strands attached to the femoral attachment site of the MCL were preserved (Table 1).

**Table 1.** Radiological and Clinical Data of the Knees That Underwent the FORM in Total Knee Arthroplasty

| No. | Sex | Age (yr) | HKA (°) | | ROM (°) | | Knee score | | Function score | | PE | FORM[a] | Valgus laxity[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Preop | Postop | Preop | Postop | Preop | Postop | Preop | Postop | | | Preop | Postop (12 wk) | Postop (24 wk) |
| 1 | F | 81 | 164 | 181 | 90 | 110 | 43 | 70 | 60 | 65 | 12.5 | 1 | 1 | 1 | 1 |
| 2 | M | 67 | 173 | 180 | 130 | 130 | 57 | 90 | 48 | 69 | 12.0 | 1 | 1 | 1 | 1 |
| 3 | M | 68 | 166 | 180 | 110 | 120 | 45 | 90 | 34 | 75 | 12.5 | 2 | 1 | 1 | 1 |
| 4 | M | 68 | 173 | 179 | 120 | 120 | 45 | 90 | 60 | 70 | 12.5 | 1 | 1 | 1 | 1 |
| 5 | F | 77 | 169 | 178 | 130 | 130 | 45 | 70 | 58 | 65 | 12.0 | 2 | 1 | 1 | 1 |
| 6 | F | 63 | 158 | 180 | 110 | 120 | 45 | 85 | 33 | 65 | 12.0 | 2 | 1 | 1 | 1 |
| 7 | F | 85 | 160 | 181 | 140 | 140 | 30 | 75 | 50 | 60 | 12.0 | 3 | 1 | 2 | 1 |
| 8 | M | 68 | 171 | 184 | 100 | 110 | 80 | 80 | 79 | 70 | 10.0 | 1 | 2 | 1 | 1 |
| 9 | F | 72 | 172 | 180 | 130 | 120 | 57 | 70 | 40 | 63 | 12.5 | 1 | 1 | 1 | 1 |
| 10 | F | 63 | 164 | 182 | 120 | 130 | 70 | 80 | 48 | 65 | 10.0 | 1 | 1 | 1 | 1 |
| 11 | M | 75 | 163 | 179 | 100 | 120 | 80 | 80 | 53 | 66 | 12.0 | 3 | 2 | 2 | 1 |
| 12 | M | 67 | 154 | 180 | 100 | 120 | 75 | 80 | 60 | 68 | 10.0 | 3 | 1 | 1 | 1 |
| 13 | M | 67 | 170 | 181 | 120 | 120 | 44 | 55 | 68 | 65 | 10.0 | 1 | 1 | 1 | 1 |
| 14 | F | 84 | 168 | 178 | 110 | 120 | 45 | 60 | 33 | 60 | 10.0 | 1 | 2 | 1 | 1 |
| 15 | F | 69 | 160 | 179 | 120 | 130 | 55 | 65 | 70 | 85 | 14.0 | 3 | 1 | 2 | 1 |
| 16 | F | 70 | 169 | 178 | 110 | 120 | 42 | 80 | 60 | 65 | 12.0 | 3 | 1 | 2 | 1 |
| 17 | F | 84 | 172 | 172 | 120 | 120 | 60 | 70 | 36 | 60 | 10.0 | 2 | 2 | 1 | 1 |

FORM: femoral origin release of the medial collateral ligament, HKA: hip-knee-ankle, Preop: preoperative, Postop: postoperative, ROM: range of motion, PE: thickness of polyethylene bearing used.

[a]1: 1/3 release of the medial collateral ligament (MCL), 2: 2/3 release of the MCL, 3: 3/3 release of the MCL, [b]Grade 1: ≤5°, grade 2: 5°–10°, and grade 3: >10°.

There was no knee with preoperative valgus instability of >grade 2. On the radiological evaluation, the HKA angle was changed from 166°±8° preoperatively to 180°±2° postoperatively (p<0.001). On the postoperative clinical evaluation, there were 4 knees with valgus instability of >grade 2 at postoperative 12 weeks. At postoperative 24 weeks, however, the valgus instability grade was improved to grade 1 in all of these 4 knees. The mean Knee Society knee score improved from 54±15 points (range, 30 to 84 points) preoperatively to 76±10 points (range, 55 to 90 points) postoperatively (p=0.001). The mean Knee Society function score improved from 52±14 points (range, 33 to 79 points) preoperatively to 67±6 points (range, 60 to 85 points) postoperatively (p=0.001). The mean preoperative ROM was 115°±13° (range, 90° to 140°), and the mean postoperative ROM was 122°±8° (range, 110° to 140°) (p=0.008). No knees showed extension lag postoperatively.

## Discussion

The present report describes a novel stepwise method of medial release in TKA in knees with varus deformity. The FORM technique provided as sufficient medial gap opening as we expected in all knees. In addition, there was no remnant valgus instability at 24 weeks after surgery. Although further investigations should be conducted to confirm the safety, efficacy, and superiority of the technique, we think that this technique can be advantageous over other methods of medial release, such as periosteal stripping of tibial insertion of the superficial MCL, pie-crusting of midsubstance of the MCL, and medial epicondylar osteotomy.

First, our medial release technique can be performed in a stepwise manner under direct visualization. Traditionally, the tibial insertion of the superficial MCL is stripped when release of the deep MCL, POL, and semimembranosus is insufficient to obtain a rectangular gap[1,3]. However, this maneuver can only be performed indirectly because the broad tibial insertion of the superficial MCL is not totally exposed. Sometimes, surgeons encounter an embarrassing situation of over-release of the superficial MCL[2,7]. Some cadaveric studies have reported the pie-crusting technique can result in insistent and unpredictable medial release[4,5]. Compared with the medial epicondylar osteotomy, the FORM is beneficial in that it allows for stepwise release. Since the medial epicondylar osteotomy causes complete detachment of the femoral insertion of the MCL, delicate control of medial release cannot be achieved with this method. As mentioned earlier, an all or nothing circumstance happens not only in tibial stripping of the superficial MCL but also in medial epicondylar osteotomy[9].

Second, adequate soft tissue healing, which is adapted to the widened medial space, can be expected after FORM because it preserves soft tissue anchor adjacent to the femoral insertion of the MCL. Complete periosteal stripping of the superficial MCL promotes bone-to-soft tissue healing, which has been associated with inferior outcome compared to bone-to-bone healing[12,13]. To the best of our knowledge, there is no relevant study comparing soft tissue-to-soft tissue healing and bone-to-soft tissue healing. However, we think that un-decorticalized bone-to-soft tissue healing is less predictable than soft tissue-to-soft tissue healing. In addition, relatively abundant blood supply, such as condylar vessels, near the site of the FORM may provide better healing potential[12]. Although it was studied with Achilles tendon-calcaneus model, homogenous tissues (bone-to-bone and tendon-to-tendon) showed better healing quality than did healing between heterogenous tissues (bone-to-tendon)[14]. Furthermore, healing of the distally detached MCL requires a broader region for healing compared to that of the proximally detached MCL; this may be because the tibial insertion of the superficial MCL is substantially broader than its femoral insertion[11]. However, this speculation has not been supported by scientific evidence; thus, further comparative studies are necessary. In the original report on the medial epicondylar osteotomy, only 54% of the knees achieved bone union, 46% of the osteotomy was healed with fibrous union, and unpredictable heterotopic ossification occurred in 36%[9]. To overcome this problem, Mullaji and Shetty[2] used additional cancellous screw fixation after sliding of the osteotomized fragment. However, the risk of nonunion and additional placement of screws may be potentially problematic. Based on our experience, we believe the FORM does not necessitate suture or fixation for healing.

Mullaji et al.[15] showed that posteromedial soft tissue release, posteromedial tibial osteotomy, and periosteal elevation of the superficial MCL from the tibial side were sufficient to correct deformity without significant postoperative instability in 173 knees with varus deformity of >20°. Cho et al.[16] reported successful outcome of partial release of the MCL from the tibial side only performed in 176 out of 209 knees during primary TKA. The remaining 33 knees that underwent complete MCL tibial release showed no significant valgus instability compared with the partial release group. Although there are numerous studies that describe medial soft tissue release from the tibial side, Hunt et al.[17] and Mihalko et al.[1] pointed out the lack of evidence to support the efficacy of current tibial side medial release techniques, necessity of standardized release sequences, and possibility of iatrogenic injury and instability. Several researchers proposed that the MCL

**Table 2.** Comparison of Radiographic and Clinical Outcomes of Recent Studies on Different Medial Tissue Release Techniques in Total Knee Arthroplasty

| Study | Medial release technique | No. of knees | F/U (mo) | Preop HKA (°) | Postop HKA (°) | Postop KS | Postop FS | Postop ROM (°) |
|---|---|---|---|---|---|---|---|---|
| Mullaji and Shetty[2] | Medial epicondylar osteotomy (femur) | 12 | ≥24 | 159±7 | 178±1.5 | 92 (86–100) | N/A | 112.5 (100–124)[a] |
| Verdonk et al.[3] | Deep MCL elevation (tibia) | 255 | 12 | 174±4 | 179±3 | 92±8 | 90±13 | 121±12 |
| | Deep MCL elevation (tibia)+pie-crusting of superficial MCL | 87 | 12 | 172±5 | 179±3 | 92±9 | 87±15 | 122±9 |
| | Deep MCL elevation (tibia)+superficial MCL elevation (tibia) | 17 | 12 | 169±4 | 178±2 | 89±10 | 92±10 | 120±12 |
| Sim et al.[8] | Superficial MCL elevation (tibia) | 9 | 46.5 | 161.2±7.1 | 179.3±1.0 | 95.1±3.0 | 82.5±8.9 | 118.8±11.3[a] |
| | Medial epicondylar osteotomy (femur) | 11 | 39.8 | 163.0±3.8 | 179.9±0.8 | 91.1±4.4 | 88.2±8.7 | 119.1±13.0[a] |
| Cho et al.[16] | Superficial MCL elevation (tibia, partial) | 176 | 12 | 170.5±3.9 | 178.7±2.6 | 97.6±4.3 | 66.2±11.1 | 123±9 |
| | Superficial MCL elevation (tibia, complete) | 33 | 12 | 167.0±5.6 | 178.7±2.8 | 96.0±7.0 | 65.9±8.8 | 116±12 |
| Koh and In[18] | Deep MCL elevation (tibia) | 73 | 12 | 169.4 (154.7–174) | 180.1 (174.1–186.7) | 93 (57–100) | 89 (45– 100) | 130.1 (87–150) |
| | Deep MCL elevation (tibia)+semimembranosus release (tibia) | 24 | 12 | | | | | |
| | Deep MCL elevation (tibia)+semimembranosus release (tibia)+pie-crusting of superficial MCL | 7 | 12 | | | | | |
| Current study | Femoral origin release of the medial collateral ligament | 17 | 8 | 166±8 | 180±2 | 76±10 | 67±6 | 122±8 |

Values are presented as mean±standard deviation or mean (range).
F/U: follow-up, Preop: preoperative, HKA: hip-knee-ankle, Postop: postoperative, KS: knee score, FS: function score, ROM: range of motion, N/A: not applicable, MCL: medial collateral ligament.
[a]Maximal angle of the knee flexion (°).

pie-crusting technique were effective in varus deformity correction during TKA[18-20]. It has been recently reported, however, that this technique led to unpredictable gap increments and frequent early over-release[5,19]. Finally, medial femoral epicondylar osteotomy has been proposed as an alternative to the medial tissue release technique[2,8,9]. In spite of its efficacy and safety, the medial epicondylar osteotomy led to significant coronal and transverse plane laxity compared with the conventional subperiosteal elevation of the MCL from the tibial side in the study by Mihalko et al.[21]. Furthermore, reports on the medial epicondylar osteotomy have some limitations such as the relatively short-term study period and lack of systematic comparison with other techniques. A summary of our literature review on the currently available techniques is presented in Table 2.

The present report has several limitations. First, data on the intraoperative mediolateral gap measurements after the conduction of the FORM were not described. Therefore, we could not provide conclusive results on the proportional gap increments according to each step of the FORM. In further investigation, the relationship between gap increment and each step of the FORM should be determined using a gap measuring device or computer navigation. In addition, it should be evaluated whether the FORM changes extension and flexion gap independently. Second, our results are based on a small sample size with short-term follow-up without a comparison with knees that underwent tibial side MCL release or medial epicondylectomy. Third, we could not distinguish the superficial and deep MCL femoral attachment sites during busy operation. Therefore, detailed anatomy of the femoral attachment site of the MCL during the FORM procedure should be evaluated in the near future. Finally, there can be a concern about over-release of the MCL during FORM despite the delicate stepwise release. Although we did not observe over-release in our patients, we suppose that repair of the MCL femoral origin can be managed using a suture anchor or pull-out suture. In our opinion, despite these limitations, the significance of this study is that it is the first report on the proximal soft tissue releasing technique during medial release of TKA.

## Conclusions

A novel stepwise medial release of the femoral origin of the MCL may provide one of the options to correct severe varus deformity in TKA. We believe that this technique is a simple, predictable method that requires no additionally repair procedure. Because the soft tissue envelop adjacent to the femoral origin of the MCL is preserved with this technique, we can expect better soft tissue healing compared to the complete distal release of the superficial MCL. However, the safety, reproducibility, and efficacy of this technique should be thoroughly evaluated to be utilized as an alternative to the medial release technique.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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